**BELLCOMM, INC.**
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Thermal Implications of "End-Pointing" vs. "Side-Pointing" For Workshop B - Case 620

DATE: March 15, 1968

FROM: D. J. Belz

## ABSTRACT


This memorandum comments on an MSFC analysis of end-pointing versus side-pointing for Workshop B. That analysis indicates that the primarily passive Workshop A thermal control system (TCS) is not feasible for an end-pointed Workshop B, but is feasible for a side-pointed Workshop B. It appears that the latter case, although feasible, would be constrained to a lower internal heat rejection capability than Workshop A when deployed in an orbit having a 50° inclination. An active TCS introduces no inherent restriction that would limit the Workshop B design to either side-pointing or end-pointing.

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MEMORANDUM FOR FILE

## 1.0 BACKGROUND

MSFC has performed a preliminary analysis of end-pointing versus side-pointing for a solar oriented Workshop B.* Thermal aspects of each pointing mode are discussed in Reference 1, where primary emphasis is placed on a comparison of alternative insulation schemes for the Workshop external wall. This memorandum constitutes a brief review of Reference 1.

MSFC's thermal analysis is based on a simplified two-dimensional analytical model. The rate of heat generation (Q) within the Workshop required to maintain a constant (70°F) cabin-atmospheric temperature is calculated; temperatures on the interior of the Workshop's walls are obtained as a "by-product" of the analysis. Values of Q reported for several wall-insulation/thermal-coating schemes include the effects of Earth-emitted radiation and orbital transients in direct and Earth-reflected solar radiation. Heat transfer accounted for within the Workshop was limited to circumferential conduction around the wall and radial conduction/radiation through the wall. Only one set of orbital parameters was considered: a 260 NM circular orbital altitude with a $\beta$ angle of 73.5°, i.e., the maximum $\beta$ for an assumed 50° inclination of the orbital plane relative to the equatorial plane (Reference 2).**

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* End-pointing denotes that orientation for which the longitudinal or "symmetry" axis of the Workshop is parallel to the solar rays; side-pointing denotes an orientation for which the symmetry axis of the Workshop is normal to the solar rays and is contained within the orbital plane.

**$\beta$=Complement of the angle between the earth/sun line and a normal to the orbit plane. At $\beta$ = 73.5° and a circular orbit altitude of 260 NM, the Workshop is continuously exposed to direct sunlight.

MSFC's calculations were carried out for four assumed wall cross sections:

1. Current SIVB shell and polyurethane foam lining plus standoff meteoroid bumper. Emissivities of the SIVB shell's outer face and bumper's inner face equal to 0.9.

2. Current SIVB shell and polyurethane foam lining plus standoff meteoroid bumper. Emissivities of the SIVB shell's outer face and bumper's inner face equal to 0.05.

3. Current SIVB shell and polyurethane foam lining plus standoff meteoroid bumper. MDA-type superinsulation ($K = 5. \times 10^{-4}$ Btu/Hr/ft$^2$/°R) wrapped around SIVB shell under the bumper.

4. Current SIVB shell and polyurethane foam lining plus standoff meteoroid bumper. Multiple layers of aluminized mylar (sufficient to provide $K = 2.5 \times 10^{-5}$ Btu/Hr/ft$^2$/°R) wrapped around SIVB shell under the bumper.

The first cross-section corresponds to the current baseline design of Workshop A.* The second cross-section is that currently under study within MSFC (and McDonnel Douglas - St. Louis) for Workshop A as a possible revision to the current baseline. The potential change in emissivities would reduce the sensitivity of the Workshop to the external thermal environment and vehicle orientation at the price of requiring an active heat rejection capability for the Workshop. Assuming that nominal conductivities of superinsulation could be achieved on Workshop B,** the third and fourth cross-sections would provide a greater reduction in the vehicle's

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* Q values reported in Reference 1 for this cross-section were obtained from current Workshop A studies (Reference 2); as a result, the effects of thermal ducts/curtains are reflected in the reported Q's.

**Inadequate venting of superinsulation significantly increases its conductivity in comparison with its optimum (vacuum) performance; it is therefore difficult to predict the flight-performance conductivity of superinsulation wrapped around the SIVB shell. In addition, such insulation might be compressed prior to deployment of the bumper, since the bumper must be kept under tension to eliminate otherwise unacceptable panel flutter or increased bumper weight. The uncertainty in spring-back characteristics of superinsulation would further decrease confidence in predicting its flight-performance conductivity.

thermal sensitivity to attitude and incident heat flux than is likely to be achieved by reducing the emissivities of the SIVB shell and meteoroid bumper as in the second cross-section described above.

## 2.0 MSFC CONCLUSIONS

Conclusions drawn in Reference 1 are as follows:

1. "The current Workshop A insulation system with thermal control coatings designed for passive rejection of internal heat can effectively control the sidewall heat leak and internal surface temperature for a side-pointing orientation of the Workshop." This "system would be limited in the maximum internal heat rejection capability to that of Workshop A."

2. For an end-pointing orientation, the Workshop A thermal control system requires more than 3,000 watts of internal heat generation to maintain a 70°F "air" temperature; at the same time, internal surface temperatures would be below the condensation temperature of the minimum absolute humidity required for crew comfort. Increasing the internal heat generation sufficiently to elevate wall temperatures above the minimum condensation temperature would "probably result in raising the cabin temperature substantially above 70°F."

3. With an active heat rejection system and either the Workshop A insulation plus low emissive coatings or a superinsulated shell, Workshop B can maintain a 70°F gas temperature and acceptable internal surface temperatures with either a side-pointing or end-pointing orientation.

## 3.0 LIMITATIONS OF MSFC ANALYSIS

The thermal model employed in Reference 1 neglects several significant effects in achieving a simplified analysis. As stated in that reference, these effects include:

a. Shadowing of the Workshop by solar arrays and radiative heat exchange between array panels and the meteoroid bumper or vehicle skin.

b. Radiative heat exchange within the Workshop.

c. Heat transfer through the ends of the Workshop.

## 4.0 ASSESSMENT

MSFC's analysis as reported in References 1 and 2 points to the following conclusions with which the author concurs:

a. The Workshop A thermal control system is not feasible for an end-pointed Workshop B.

b. The Workshop A thermal control system is feasible for a side-pointed Workshop B.

c. A primarily active thermal control system introduces no inherent restriction that would limit the Workshop B design to either side-pointing or end-pointing; an active system appears capable of maintaining an acceptable thermal environment for either vehicle attitude.

Their conclusion that a side-pointed Workshop B utilizing the thermal control system of Workshop A "would be limited in the maximum internal heat rejection capability to that of Workshop A" appears to be optimistic. Workshop A is scheduled to be placed in a circular orbit at a 230 NM altitude with an orbital inclination of 28.5° relative to the equator. The maximum value of $\beta$ corresponding to an inclination of 28.5° is 52°. At $\beta = 52°$, Workshop A will be exposed to incident thermal radiation directly from the Sun during ~70% of an orbital period. For Workshop B, launched into an orbital plane inclined 50° relative to the equatorial plane, the maximum value of $\beta$ is 73.5°. At $\beta = 73.5°$, Workshop B (altitude 260 NM) will be exposed to direct sunlight during the entire orbital period. The orbit-averaged direct solar flux incident on a side-pointed Workshop B will thus be ~43% greater than the direct solar flux on Workshop A (side-pointed during AAP 3-4). In the overall heat balance of Workshop B, relatively more heat is supplied by solar radiation than in Workshop A; less internal heat generation is required to maintain the same temperatures within Workshop B than in Workshop A. Thus it appears that for a side-pointed Workshop B employing the thermal control system of Workshop A, the "maximum internal heat rejection capability" would be less than that of Workshop A.

## 5.0 FURTHER STUDIES

A thermal model more accurate than that employed in Reference 1, together with reasonable estimates of internal heat to be generated by crew and equipment, will be needed to define the active cooling/heating requirements for Workshop B. A "second cut" analysis might reasonably employ a three-dimensional representation of the Workshop including the effects of solar array shadowing and internal compartmentation, as well as internal and external intravehicular radiative heat exchange. Upper and lower limits on internal gas and surface temperatures should conform to the crew's thermal comfort requirements (See, for example, the MSC/Medical Research and Operations Directorate's standards given in Reference 3). A comparison of anticipated internal heat generation with the internal heat rates needed to maintain acceptable temperatures defines the active heating/cooling capacity required. Appropriate vehicle parameters would include side-pointing/end-pointing orientations and insulation schemes as in Reference 1. In addition, β angles of 0° (extreme cold case) as well as 73.5° (extreme hot case for 50° inclination) should be considered. Such a study would be comparable to efforts that have already been undertaken for Workshop A and should therefore be within the existing capability of MSFC and its contractors.

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Attachment
References

## REFERENCES

1. C. Ellsworth, "Comparison of End Pointing Versus Side Pointing on Workshop B Sidewall Thermal Insulation," MSFC, Undated.

2. P. Priest, MSFC, Personal Communication, March 4, 1968.

3. J. M. Waligora, "Thermal Comfort and Tolerance Design Criteria," MSC/Biomedical Research Office, September 13, 1967.

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